PIPING PLOVER BROOD FORAGING ECOLOGY ON NEW YORK BARRIER ISLANDS

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Abstract: Effective management of piping plover (*Charadrius melodus*) populations requires knowledge of the habitats that foster successful reproduction. We studied piping plover chick foraging ecology and survival on the central barrier islands of Long Island, New York, 1992 and 1993. Within the 90-km study area, all 1-km beach segments with ephemeral pools or bay tidal flats were used for nesting and brood rearing, whereas <50% of beach segments without these habitats were used. On beach segments with ephemeral pools, broods preferred ephemeral pools to ocean intertidal zone, wrack, backshore, open vegetation, and interdune habitat. Indices of terrestrial arthropod abundance and foraging rates were greater in ephemeral pools than in other habitats. In 1992, chick survival was higher on beach segments with ephemeral pools than on segments without ephemeral pools. On beach segments with bay tidal flats, broods preferred bay tidal flats and wrack to ocean intertidal zone, backshore, and open vegetation habitats. Foraging rates in bay tidal flats were similar to those in ephemeral pools and greater than in open vegetation, wrack, and backshore habitats. On beach segments without ephemeral pools and bay tidal flats, broods preferred wrack to all other habitats, and open vegetation was second most preferred. To assist in the recovery of the piping plover, land-use planners should avoid beach management practices (e.g., beach filling, dune building, renourishment) that typically inhibit natural renewal of ephemeral pools, bay tidal flats, and open vegetation habitats.

In 1986, the Atlantic Coast piping plover population was classed as threatened owing to population declines attributed to poor reproductive success (Federal Register 1985, Dyer et al. 1988). One factor that may affect reproductive rates is the quality of foraging habitat for prefledging chicks. We must know the relative value of each habitat to adequately assess the impact of proposed coastal management projects such as beach renourishment.

In Maryland, plover chicks foraging in bay tidal flats and island interior habitats were more likely to survive than chicks foraging in ocean beach habitats, apparently because they had access to more food (Loegering and Fraser 1995). In Rhode Island, chicks foraging in the mudflats of a drawn-down salt pond were more likely to survive than chicks foraging in other habitats (Goldin and Regosin 1998).

In New York, ephemeral pools and bay tidal flats were structurally similar to high-quality habitats elsewhere (Patterson et al. 1991, Loegering and Fraser 1995, Goldin and Regosin 1998). The goal of this study was to determine whether brood-rearing quality of beaches with ephemeral pools or bay tidal flats was superior to the quality of beaches without these habitats on the central New York barrier islands. We tested the following hypotheses: (1) piping plovers are more likely to nest on beach segments with ephemeral pools or bay tidal flats; (2) where available, broods prefer ephemeral pools and bay tidal flats to ocean intertidal zone, wrack, backshore, open vegetation, and interdune habitats; (3) ephemeral pools and bay tidal flats support more terrestrial arthropods than other habitats; (4) foraging rates in ephemeral pools and bay tidal flats are greater than in other habitats; and (5) survival rates of chicks are higher on beach segments with ephemeral pools or bay tidal flats than on segments without these 2 habitats.

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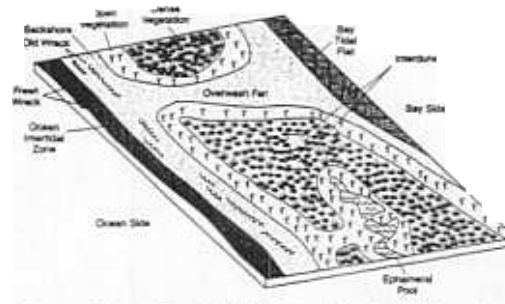
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Fig. 1. Schematic of habitats available to piping plover broods on New York barrier islands, 1992 and 1993.

STUDY AREA

The study area comprised 90 km of beach-front along 3 barrier islands between Jones Inlet and Shinnecock Inlet, New York. It included the western 25 km of Jones Beach, all 53 km of Fire Island, and the western 12 km of West-hampton Beach (the western 2 km was not accessible in 1993 because the beach was closed following storm destruction).

Ephemeral pools (10–35,000 m²) occurred on Jones Beach, in the upper backshore just seaward of, or within, the primary dunes (Fig. 1). They formed where sea and–or rainwater pooled during storm overwashes and rains. As the water evaporated, moist sand was exposed until the next storm refilled the pool.

Bayside tidal flats occurred at the western end of Fire Island in 1992 and 1993 where sand overtopped the jetties and created sandspits in Fire Island inlet. They were largely unvegetated sandy or muddy areas exposed at low tide. In the winter of 1992–93, storms breached the middle section of the Westhampton area, forming Little Pike's Inlet and vegetation-free over-wash fans (Fig. 1). Here, bay tidal flats became accessible to broods in 1993.

Habitats available to plovers on all beaches included ocean intertidal zone, backshore (dry sandy beach shoreward of the high tide line and seaward of the dune line, if present), wrack (material deposited on the intertidal zone and backshore by waves and tide, mostly eelgrass, *Zostera marina;* Fig. 1), and open vegetation (mostly American beach grass, *Ammophila breviligulata;* mean coverage = 21%, median coverage = 10%). Interdune (bare sand areas within open vegetation) was available, except on bay tidal flat segments.

Beaches were 10–370 m wide, measured from mean high tide to the bay, dense vegetation (too thick for a plover chick to walk through), or buildings, whichever was closest to the ocean. Dunes were < 1–10 m high. Human use varied from no buildings and few pedestrians, to dense communities with many bathers and off-road vehicles (ORV's). Potential predators included red foxes (*Vulpes vulpes*), common and fish crows (*Corvus brachyrhynchos* and *C. ossifragus*), gulls (*Larus* spp.), and domestic cats.

METHODS

Habitat Availability

We divided the study area into 1-km segments, based on average brood movements from nest to foraging sites of 131–850 m on Assateague Island, Virginia (Loegering 1992).

Table Piping plover use of beach segment habitat types for nesting on New York barrier islands, 1992 and 1993.

	Beach segment type					
	Ephemeral pools or bay tidal flats available[a]		Ephemeral pools and bay tidal flats unavailable[a]			
Beach segment use 1992						
Nesting	9	100	33	41		
No nesting	0	0	48	59	32.2[b]	<0.0001
Beach segment use 1993						
Nesting	12	100	26	34		
No nesting	0	0	50	66	18.3[b]	<0.0001
No. pairs nesting 1992	32	41	47	59	81.7[c]	<0.0001
No. pairs nesting 1993	46	56	36	44	125.5[c]	<0.0001

[a] Habitats available on all beach segment types were: ocean intertidal zone, wrack, backshore, open vegetation, and interdune, except on bay tidal flat segments.

[b] Chi-square value for test of equal proportions, 1 df.

[c] Chi-square test of the hypothesis that pairs nested on segments randomly with respect to habitats available, 1 df.

Table 2. Availability (mean % of total beach width) and use (mean % of time spent in each habitat) of habitats by piping plover broods, age 3–25 days, by beach segment type, on New York barrier islands, 1992 and 1993. For availability, n = the number of 1-km brood-rearing beach segments sampled for that type; for use, n = the number of broods sampled by beach segment type.

Habitat type	Availability[a]			Use[b]			Rank[c]
				$\bar{x}$ %	SE		
Ephemeral pools available, 1992							
Ephemeral pools	7	20.5	5.65	22	65.9	6.14	5 A
Open vegetation	7	16.2	2.32	22	19.1	4.19	4 B
Wrack	7	0.9	0.32	22	1.9	0.10	3 C
Interdune	7	14.8	4.00	22	11.2	4.46	2 C
Backshore	7	36.4	7.80	22	1.8	0.79	1 CD
Ocean intertidal zone	7	11.2	1.37	22	0.0	0.00	0 D
Ephemeral pools available, 1993							
Ephemeral pools	7	14.3	2.90	28	80.3	4.64	5 A
Wrack	7	0.7	0.17	28	2.8	1.15	4 B
Open vegetation	7	23.7	1.72	28	13.6	4.24	3 B
Interdune	7	15.9	2.81	28	2.9	1.04	2 C
Ocean intertidal zone	7	9.8	0.87	28	0.2	0.15	1 C
Backshore	7	35.6	3.15	28	0.3	0.26	0 D
Bay tidal flats available, 1993							
Bay tidal flats	4	10.0	3.24	6	56.9	15.47	4 A
Wrack	4	3.0	2.32	6	26.4	9.23	3 AB
Open vegetation	4	6.6	3.77	6	12.6	9.07	2 BC
Ocean intertidal zone	4	11.6	5.21	6	0.0	0.00	1 C
Backshore	4	68.8	6.81	6	4.0	1.49	0 C
Ephemeral pools and bay tidal flats unavailable, 1992							
Wrack	24	2.3	0.40	26	38.8	5.13	4 A
Open vegetation	24	21.4	2.20	26	40.6	5.48	3 B
Backshore	24	42.1	2.52	26	15.1	3.11	2 C
Interdune	24	5.2	2.07	26	0.0	0.00	1 D
Ocean intertidal zone	24	29.1	1.73	26	5.5	2.56	0 D
Ephemeral pools and bay tidal flats unavailable, 1993							
Wrack	16	1.4	0.41	15	50.0	5.00	4 A
Backshore	16	54.0	2.31	15	26.0	5.30	3 B
Open vegetation	16	16.1	2.23	15	18.2	3.95	2 B
Interdune	16	1.4	0.66	15	0.0	0.00	1 C
Ocean intertidal zone	16	27.2	1.27	15	5.8	1.64	0 C

[a] Availability = habitat width (m) × 100/entire beach width (m) measured along transects perpendicular to the shoreline. Habitats available on all beach segment types were: ocean intertidal zone, wrack, backshore, open vegetation, and interdune, except on bay tidal flat segments.

[b] Use = mean % of instantaneous samples taken at 10 sec intervals during 5-min behavioral observations.

[c] Overall use differed significantly from random for all 3 beach segment types (ephemeral pools available: Wilk's λ = 0.025, F = 132.33, 5 df, P = 0.0001, or P = 0.001 by randomization for 1992, and Wilk's λ = 0.029, F = 156.64, 5 df, P = 0.0001, or P = 0.001 by randomization for 1993; bay tidal flats available: Wilk's λ = 0.014, F = 35.74, 4 df, P = 0.027, or P = 0.029 by randomization for 1993; ephemeral pools and bay tidal flats unavailable: Wilk's λ = 0.145, F = 32.55, 4 df, P = 0.0001, or P = 0.001 by randomization for 1992; Wilk's λ = 0.058, F = 44.82, 4 df, P = 0.0001, or P = 0.001 by randomization for 1993). Subsequently, habitats were ranked and those with different letters were significantly different (pairwise t-tests for mean log-ratio differences between habitats, P < 0.05).

We calculated an index to habitat availability by measuring the width of each habitat type on a transect perpendicular to the ocean shore. We expressed the result as a percent of total beach width.

In each segment, we randomly placed 4 transects extending from ocean to bay, continuous dense vegetation, or buildings, whichever was closest to the ocean. In May 1992 and 1993, we measured the width of each habitat. We measured at mid-tide ±1.5 hr so that the average widths of the intertidal zone centered around mid-tide. To estimate the relative availability of habitats on each 1-km segment, we averaged the measured transect lengths in each habitat on all 4 transects, then divided by the average total transect length and multiplied by 100. Beach physiognomy was such that 4 random transects were sufficient to capture all habitats present in a segment. We classified segments as ephemeral pools available if they contained all or any portion of an ephemeral pool, or as bay tidal flats available if they contained all or any portion of a bay tidal flat. Otherwise, we classified segments as ephemeral pools and bay tidal flats unavailable.

Table 3. Relative indices of arthropod abundance and foraging rates (pecks per min) of piping plover broods, age 3–25 days, within various habitats on New York barrier islands, 1992 and 1993. For arthropod abundance, n = the number of 1-km segments sampled; for foraging rates, n = the number of broods sampled in each habitat.

Year/Habitat	Relative arthropod abundance			Pecks/min		
	n^a	$\bar{x}^{c,d}$	SE	n^b	$\bar{x}^d$	SE
1992						
Ephemeral pools	5	57 A	6.3	22	15.5 A	0.93
Ocean intertidal zone				4	8.3 B	2.99
Open vegetation	17	28 C	3.1	35	6.8 C	1.08
Wrack	17	15 B	1.3	22	6.4 C	1.05
Backshore				18	4.2 D	0.85
1993						
Ephemeral pools	3	114 A	30.9	26	13.2 A	1.14
Bay tidal flats	3	40 AB	20.9	5	10.4 A	1.45
Ocean intertidal zone	9	14 BC	3.6	11	9.8 A	2.00
Wrack	20	14 BC	1.5	22	5.2 B	0.62
Open vegetation	13	16 BC	3.7	27	4.4 BC	0.64
Backshore	20	12 C	1.1	21	3.7 C	0.56

[a] Arthropods were captured during a 3 hr period using pairs of paint stirrers (1 stick vertical, 1 horizontal) coated with Tanglefoot Insect Trap Coating, once per week, for 7 weeks. Sample sizes vary because not all 1-km beach segments sampled contained every habitat.

[b] Brood sample sizes vary because not all broods used all habitats.

[c] Count of arthropods in each habitat (one pair of sticky paint stirrers/habitat), averaged across 7 weeks and n 1-km beach segments.

[d] Means with the same letters are not different (pairwise Wilcoxon rank-sum test preceded by Kruskal-Wallis tests for differences among means, $P < 0.05$).

Habitat Use and Foraging Rates

To minimize the effects of time of day and tide on comparisons among the 3 beach segment types, we sampled broods as uniformly as possible over 3 times a day [morning (0600 to 1000 hr), midday (1000 to 1400 hr), and afternoon (1400 to 1800 hr)]. Similarly, we sampled as uniformly as possible over 4 tidal stages [high-tide-falling (high tide + 3 hr), mid-tide-falling (high tide + 3 hr to low tide), low-tide-rising (low tide to low tide + 3 hr), and mid-tide-rising (low tide + 3 hr 5 min to high tide)].

We used an instantaneous sampling method to estimate the amount of time broods spent in various habitats (Altman 1974, Lehner 1979, Tyler 1979). We searched for broods daily and attempted to sample each brood in the study area every 2 days. When we located a brood, we estimated the distance between the brood's nest and its foraging location. We then observed the first chick seen for 5 min and recorded the number of pecking and biting movements made (Tyler 1979, Tacha et al. 1985). Once every 10 sec, we recorded the habitat. If a chick's behavior was obscured by vegetation, but we were sure of the habitat type occupied, we continued the observation for habitat use. Percent use was the percent of 10-sec observations that the focal bird was in a given habitat. We included all broods aged 3–25 days in these analyses (chicks

<3 days were still nourished by their yolk sacs and had not established foraging patterns).

Arthropod Abundance and Chick Survival

We randomly selected a sample of beach segments where broods foraged and within each segment we randomly selected 2 transects perpendicular to the long axis of the beach. We sampled once a week for 7 consecutive weeks each year starting in June. We sampled each segment for 3 hr on the same day to reduce temporal variability, and in the first half of the day to avoid pedestrians in the afternoon.

We coated paint stirrers, except for the handles, with Tanglefoot® Insect Trap Coating (Tanglefoot, Grand Rapids, Michigan, USA). We set them out in pairs, with 1 stirrer stuck vertically into the sand facing into the wind, and the other laid horizontally on the ground about 10 cm away. The uncoated handle of the vertical stirrer was sunk completely into the sand. The area exposed was 21.5 cm × 3 cm for the horizontal stick and 43.0 cm × 3 cm for the vertical stick (Loegering and Fraser 1995). We placed 1 pair in each sampled habitat along each transect. In 1992, we sampled wrack, open vegetation, and ephemeral pools. In 1993, we added samples in the ocean intertidal zone, the backshore, and bay tidal flats. Except for the intertidal zone, we placed the sticks at the middle

Table 4. Number of piping plover pairs, chicks hatched and fledged, and modified Mayfield daily survival rate (DSR) estimates of chick survival, by beach segment type, on New York barrier islands, 1992 and 1993.

Beach segment type[a]	No. pairs	Hatched	Fledged	% Fledged	Chicks Fledged/pair	DSR[b] (±SE)	S[c]
1992							
Ephemeral pools available	30	69	41	59%	1.37	0.979 (0.004) A	58%
Bay tidal flats available	2	1	0	0%	0.00	0.000	0%
Ephemeral pools and bay tidal flats unavailable	47	91	38	42%	0.81	0.959 (0.008) B	35%
1993							
Ephemeral pools available	38	101	55	54%	1.45	0.975 (0.006) A	53%
Bay tidal flats available	8	23	13	57%	1.63	0.972 (0.017) A	49%
Ephemeral pools and bay tidal flats unavailable	36	42	21	50%	0.58	0.970 (0.008) A	45%
1992–93 totals	161	327	168	51%	1.04	0.971 (0.003)	48%

[a] Habitats available on all beach segment types were: ocean intertidal zone, wrack, backshore, open vegetation, and interdune, except on bay tidal flat segments.
[b] Chi-square test for homogeneity of survival among habitats; 1992: $\chi^2 = 4.26$, 1 df, $P < 0.05$; 1993: $\chi^2 = 0.33$, 2 df, $P > 0.05$. Means with the same letters are not significantly different.
[c] The interval from hatching to fledging is 25 days; interval survival (S) = DSR^{25} × 100.

of the transect section in that habitat. In the intertidal zone, we placed the sticks higher on the beach when the tide was rising (to avoid losing the sticks in the tide), and farther down the beach when the tide was falling. We identified collected arthropods to order. Counts for each habitat were averaged over the 7-week sampling period across transects (subsamples) for each segment, thus n = the number of beach segments sampled.

We searched for nests and broods from 1 April through 15 August. When we first located nests, we observed them from a distant location every 1 to 3 days ($\bar{x}$ = 2 days) to determine hatch dates. After eggs hatched, we located each brood every 1 to 3 ($\bar{x}$ = 2 days) for 25 days to count chicks. We considered chicks fledged if they survived to 25 days of age or were seen flying.

Statistical Analyses

We used chi-square tests to determine whether beach segments with ephemeral pools and bay tidal flats were occupied by nesting plover pairs more frequently than expected if plovers choose segments at random. We also tested whether numbers of plover pairs nesting in ephemeral pool or bay tidal flat segments were greater than expected if plovers chose segment types in proportion to availability.

Eighty-two percent of broods foraged within 1 beach segment. We assigned beach segments to the remaining 18% of broods according to where they did the majority of their foraging. For each year and for each of the 3 beach segment types, we ranked habitats in order of relative preference using compositional analysis (Aebischer et al. 1993).

We used Kruskal-Wallis and Wilcoxon rank-sum tests to compare foraging rates and arthropod abundance between years and among habitats. When Kruskal-Wallis tests indicated differences among habitats ($P < 0.05$), we followed with pairwise Wilcoxon rank-sum tests to determine which habitats contributed most to the overall differences (Saville 1990).

We used a modified Mayfield procedure (Flint et al. 1995) to obtain daily survival rate estimates for chicks. This procedure allowed us to estimate chick survival without assuming independent survival probabilities among brood mates. We used a chi-square test (Sauer and Williams 1989) to test for differences in daily survival rates among beach segment types.

RESULTS

Habitat Selection

Observations ($n = 479$ and $n = 517$ in 1992 and 1993, respectively) averaged 4.9 min because we truncated observations when chicks were lost from sight and not relocated, or when tape recorders failed. Numbers of broods observed were distributed among the mornings, middays, and afternoons ($n = 36$, $n = 47$, $n = 48$ in 1992, and $n = 44$, $n = 41$, and $n = 46$ in 1993, respectively), and among high-tide-falling, mid-tide-falling, low-tide-rising, and mid-tide rising ($n = 45$, $n = 38$, $n = 40$, $n = 44$ in 1992, and $n = 41$, $n = 46$, $n = 46$, and $n = 40$ in 1993, respectively).

Beach segments were used by 1–10 broods that foraged an average of 130 ± 4.9 m ($n = 541$ brood observations, $\bar{x} \pm$ SE) from their nest sites. No broods that hatched in one type of beach segment switched to another type. Eighty-two percent of broods ($n = 80$) foraged in 1 segment 100% of the time. Ten percent ($n = 10$) foraged in 1 segment $\geq 75\%$ to $<100\%$ of the time, and 8% ($n = 8$) foraged in 1 segment $\geq 56\%$ to $<75\%$ of the time.

All beach segments with ephemeral pools or bay tidal flats were used by nesting plovers, whereas fewer than half of segments without these habitats were used by birds (Table 1). Proportions of pairs using ephemeral pool or bay tidal flat segments were higher than would be expected if adult plovers were choosing segments at random (Table 1).

Habitat use was nonrandom on all 3 beach types (Table 2). On segments with ephemeral pools, broods preferred ephemeral pools to all other habitats in 1992 and 1993 (Table 2). In 1992, open vegetation ranked second and wrack third, whereas in 1993, these 2 habitats did not differ in use. Ocean intertidal zone and backshore were the lowest ranked habitats. On segments with bay tidal flats, bay tidal flats and wrack were the top-ranked habitats (Table 2). Ocean intertidal zone and backshore were the lowest ranked habitats.

On segments with neither bay tidal flats nor ephemeral pools, wrack was the top-ranked habitat. Open vegetation ranked second in 1992, and tied for second with backshore in 1993. Open vegetation use decreased significantly from 1992 to 1993 (Wilcoxon rank-sum test for differences between years, $Z = -2.64$, $P = 0.008$). Ocean intertidal zone was the lowest ranked habitat (Table 2).

Arthropod Abundance

Arthropod abundance indices were higher in ephemeral pools than in all other habitats, except for bay tidal flats in 1993 (Table 3). Arthropod abundance was greater in bay tidal flats than in backshore habitat. Between years, arthropod abundance indices differed only for open vegetation (Wilcoxon rank-sum test for differences between years, $Z = -3.43$, $P = 0.0006$).

Foraging Rates

In 1992, piping plover broods foraged at higher rates in ephemeral pools than in all other habitats (Table 3). Foraging rates in the ocean intertidal zone were greater than in all habitats other than ephemeral pools. Foraging rates in open vegetation and wrack did not differ and were greater than in backshore habitat (Table 3). In 1993, foraging rates were higher in ephemeral pools, bay tidal flats, and the ocean intertidal zone than in all other habitats. Foraging rates in wrack were greater than in backshore habitat. Foraging rates in open vegetation did not differ from wrack or backshore habitats. Arthropod abundance indices were correlated with foraging rates (Spearman's Rho $= 0.81$, $P = 0.049$, $n = 9$).

Chick Survival

In 1992, chicks on beach segments with ephemeral pools had higher daily survival rates than chicks on segments without ephemeral pools (Table 4). In 1992, only 1 chick was known to have hatched from the bay tidal flat and it disappeared when it was 1 day old. In 1993, daily survival rates of chicks among the 3 beach segment types did not differ (Table 4).

DISCUSSION

Habitat Selection

Our results suggested that brood-rearing quality of beaches with ephemeral pools and bay tidal flats were superior to beaches lacking these habitats. We did not have segments with both bay tidal flats and ephemeral pools, so we could not directly compare plover use of these habitats. However, similar arthropod counts and feeding rates suggest that they were of similar value to plover chicks.

The high arthropod abundance and foraging rates in ephemeral pools and bay tidal flats suggested that plovers' preference for these habitats was a response to plentiful food. Together, ephemeral pools and bay tidal flats produced 65% of the fledglings in the study area, although these habitats accounted for only 12% of the habitat surveyed. The high survival rates on beach segments with these habitats suggested a selective advantage for birds nesting near ephemeral pools or bay tidal flats.

The importance of bay tidal flats has been cited in other studies. On Assateague Island, Virginia, Patterson et al. (1991) and Loegering and Fraser (1995) observed that broods used overwash fans to move from the ocean beach to bay foraging areas. The Assateague Island bay beach had more arthropods than the ocean beach, and chicks reared there weighed more, foraged at higher rates, and were more likely to survive than chicks reared on the ocean beach (Loegering and Fraser 1995). At Cape Lookout National Seashore, a barrier island in North Carolina, 96% of brood observations were on bay tidal flats, even though ocean intertidal zone, backshore, wrack, and open vegetation habitats were available (McConnaughey, National Park Service, unpublished data).

The mudflats of a drawn-down coastal salt pond in Rhode Island may have been analogous to ephemeral pools in this study. In Rhode Island, survival was higher for the chicks with access to those mudflats than for chicks without such access (Goldin and Regosin 1998). The interior of Assateague Island included moist sandflats that also may have been analogous to ephemeral pools.

Preference for wrack was consistent with findings in other studies. Yaninek (1980) and Hoopes (1993) indicated that arthropod abundances were greater in wrack than on bare sand. Goldin (1993) and Hoopes (1993) confirmed that wrack was a key plover brood foraging habitat in New York and Massachusetts, respectively. Broods in our study used wrack most where ephemeral pools and bay tidal flats were unavailable, and least where ephemeral pools were available.

Broods in this study spent notably more of their time in open vegetation (up to 41%) than did plovers in nearby studies. Broods on Breezy Point, New York spent up to 13% and those on Cape Cod up to 10% of their time in dunes that included open vegetation (Goldin 1993, Hoopes

1993). One explanation may be fewer arthropods in open vegetation in other studies. Another explanation may lie in methodology. In this study, if a chick moved into open vegetation, we continued the observation if it could be seen, even if its behavior could not be ascertained, whereas in the other studies, the observation ended.

The ocean intertidal zone ranked high in relative arthropod abundance and foraging rates, but ranked low in terms of brood preference. This may be because on our study area, in general, ocean waves made the ocean intertidal zone risky to flightless plover chicks. We saw waves hit and tumble chicks in the ocean intertidal zone, after which the chicks retreated to higher points on the beach. Additionally, escape cover (old, dry wrack and vegetation) was closer to ephemeral pools and bay tidal flats than to the ocean intertidal zone.

Annual Variation

Our results suggested that food resources vary within some habitats from year to year, and that plovers respond by altering their use of habitats. The 43% decrease in arthropods of open vegetation habitat from 1992 to 1993 was accompanied by a 55% decrease in time broods spent in vegetation on beach segments without ephemeral pools or bay tidal flats. This shift was not as pronounced for broods on beach segments with ephemeral pools.

June, July, and August were warmer and drier in 1993 than in 1992 (National Climatic Data Center, data for Islip, New York; http://www.ncdc.noaa.gov/ol/climate/stationlocator.html). Warm, dry weather in 1993 could have explained the observed reduction in arthropods in open vegetation habitat, as well as better chick survival on beaches without ephemeral pools or bay tidal flats, despite less food in open vegetation. We presume predation may have an important impact on chick survival, but it is difficult to estimate that impact.

MANAGEMENT IMPLICATIONS

Differing habitat use in different areas, and in the same areas over time, indicates that plovers are adept at adventitious exploitation of food in variable environments. Therefore, it is important to maintain temporal and spatial diversity of favorable habitats, so that if one habitat is food-poor in a given year, the broods can switch to a richer habitat.

Ephemeral pools, bay tidal flats, and open vegetation, which were preferred by plovers in this and other studies (Patterson et al. 1991, Loegering and Fraser 1995), are naturally created or maintained by overwash and—or scouring by waves. Additionally, without overwash, dense vegetation may grow between beach nesting habitats and bay tidal flats, preventing broods from walking to these foraging areas (Loegering and Fraser 1995). Coastal management projects such as jetty construction, breach filling, dune building, and sand renourishment are designed to prevent overwashing and scouring. Such beach management practices seem to be at least partially responsible for the fact that bay mudflats and ephemeral pools are relatively rare on the Atlantic coast. Recovery of piping plovers from threatened status may require that these practices be limited in some areas. It also may be possible to artificially create and maintain habitats with at least some of the characteristics produced by natural scouring, but this needs to be carefully tested.

Wrack, another important foraging habitat, is degraded by ORV traffic on the beach (Godfrey et al. 1978, Goldin 1993) and should be protected. Other factors determining the distribution and abundance of wrack are poorly understood, and should be the subject of future study.

ACKNOWLEDGMENTS

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